Federation Credibility Challenges

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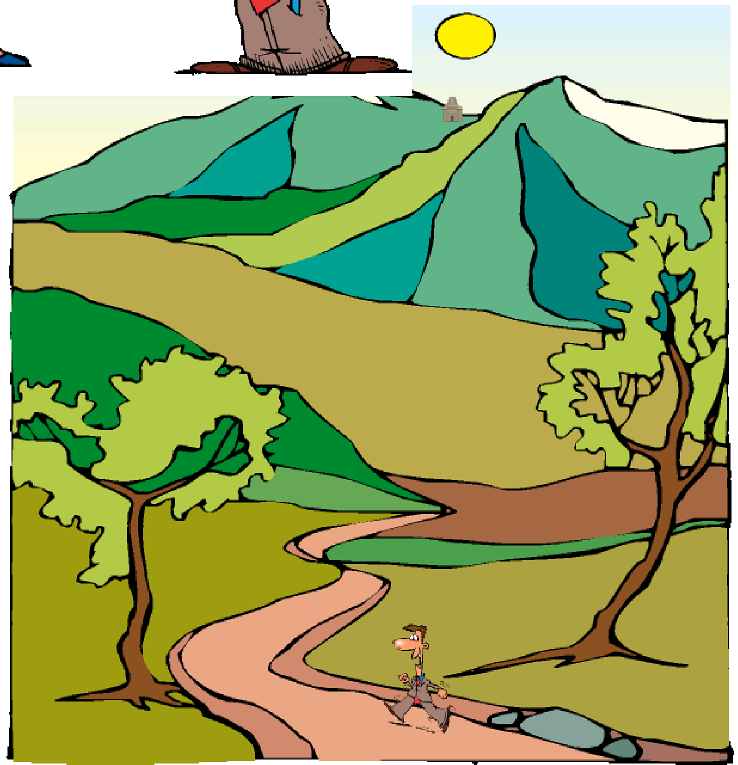
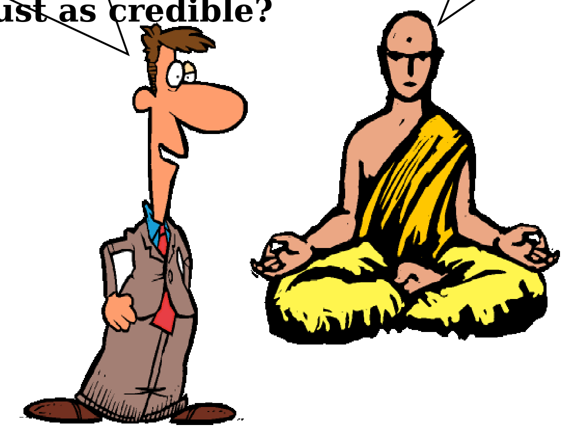
Searching for Federation Credibility

Find out how to build a credible distributed simulation from credible components.

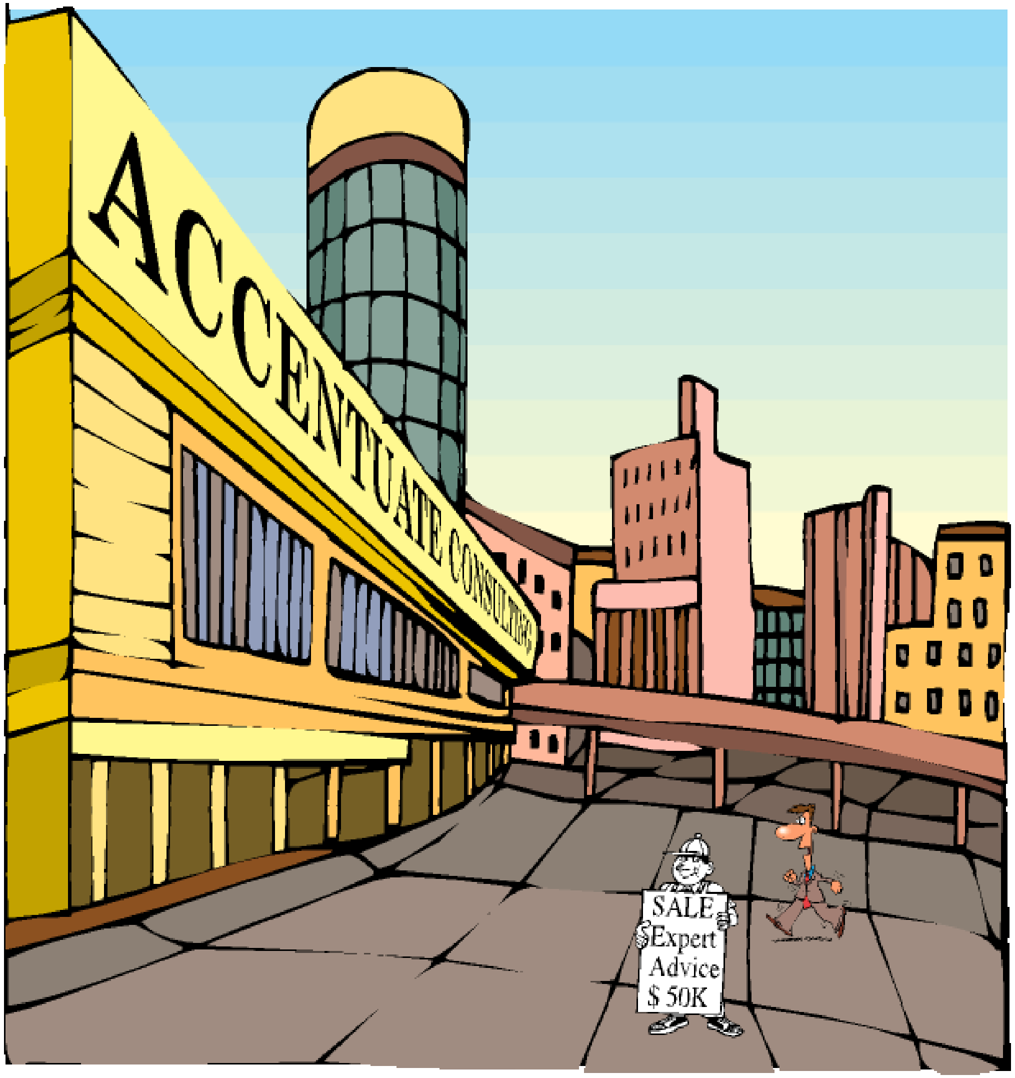


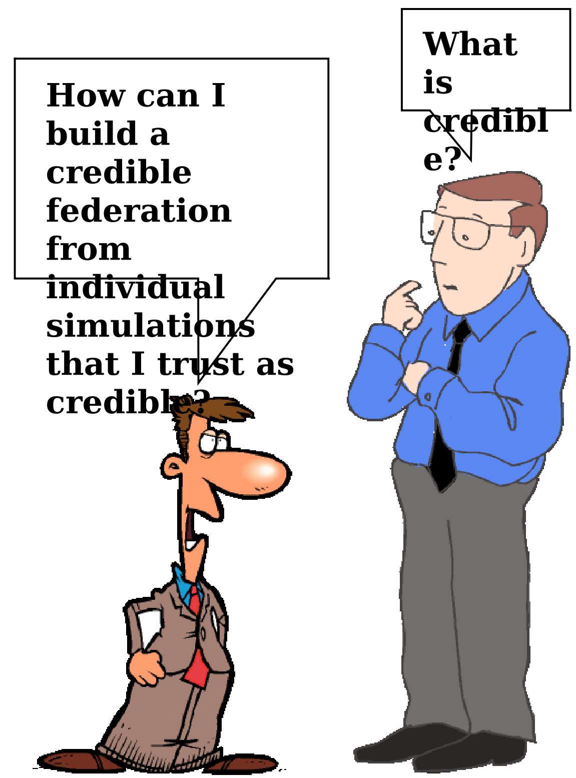
How can I build a credible federation from individual simulations that I trust as credible?

What is simulation

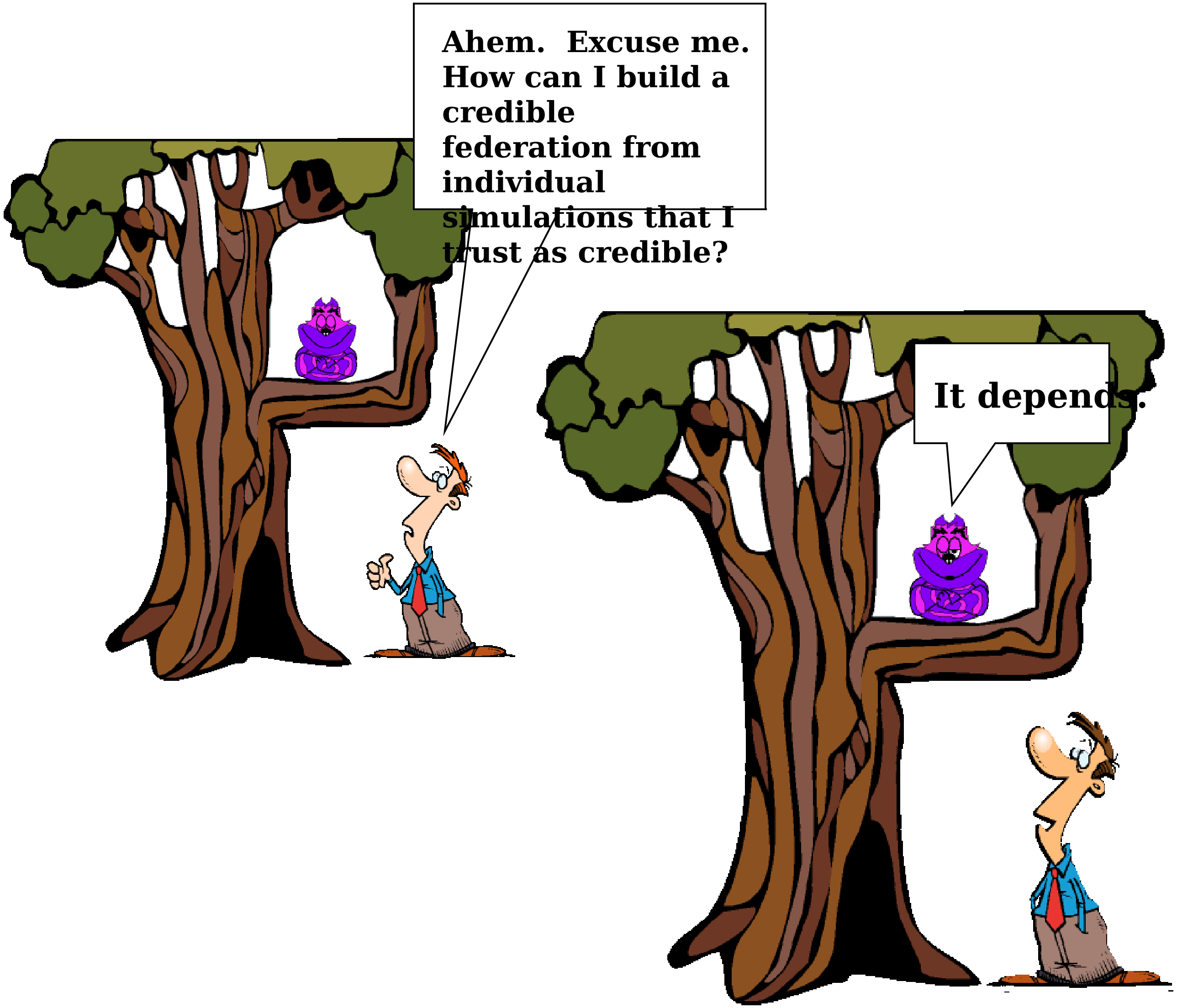


Searching for Federation Credibility

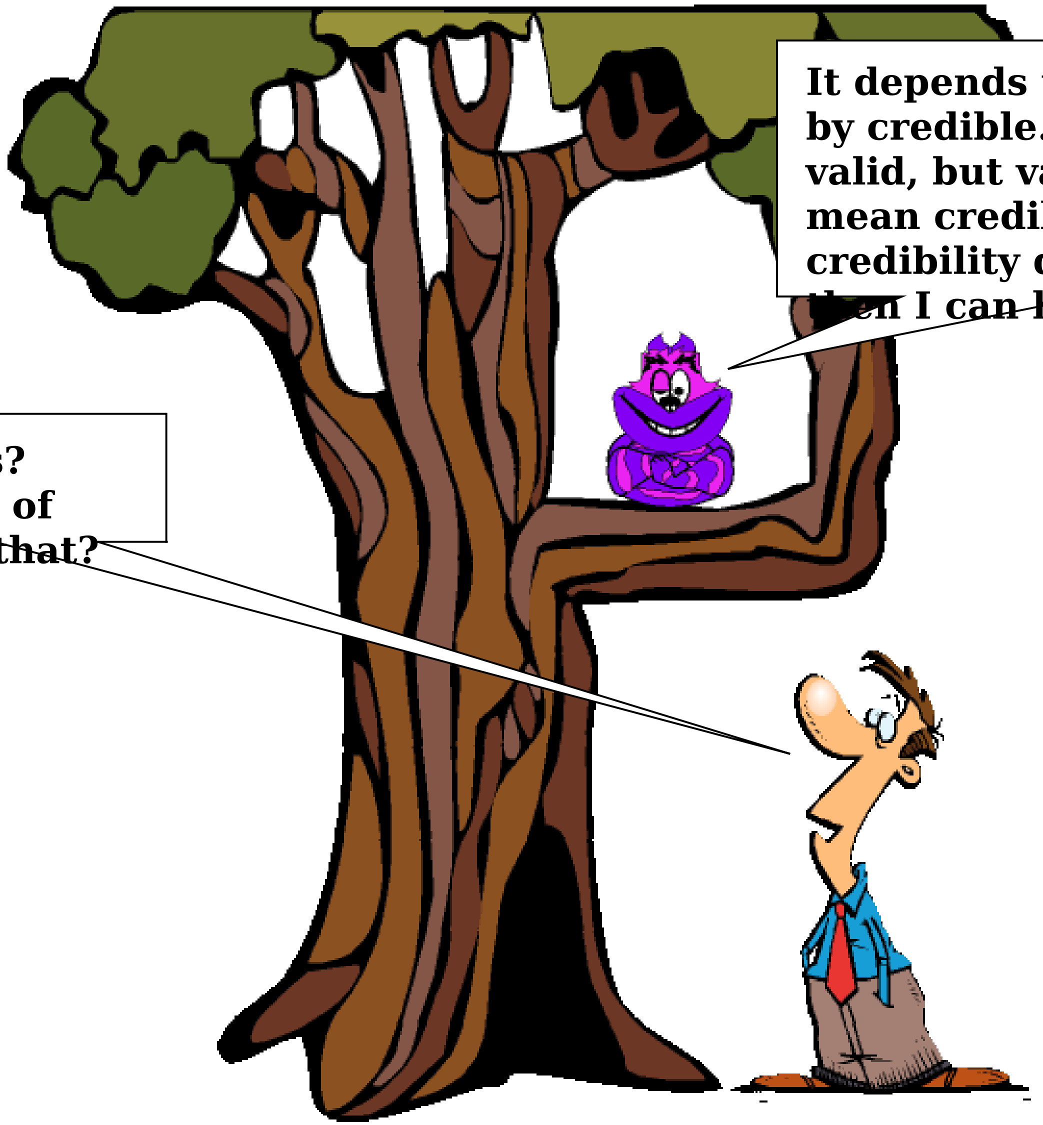




Searching for Federation Credibility



Searching for Federation Credibility

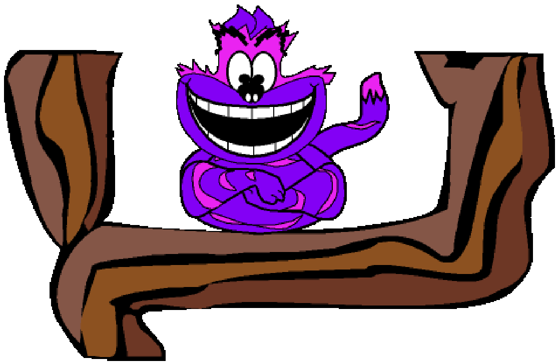


It depends upon what you mean by credible. Credible means valid, but valid does not always mean credible. If, for you, credibility depends upon validity then I can help.

It depends? What kind of answer is that?

Definitions of Interoperability Terms

Many factors affect the validity of a simulation federation incorporating valid federates. These factors fall into two broad categories:



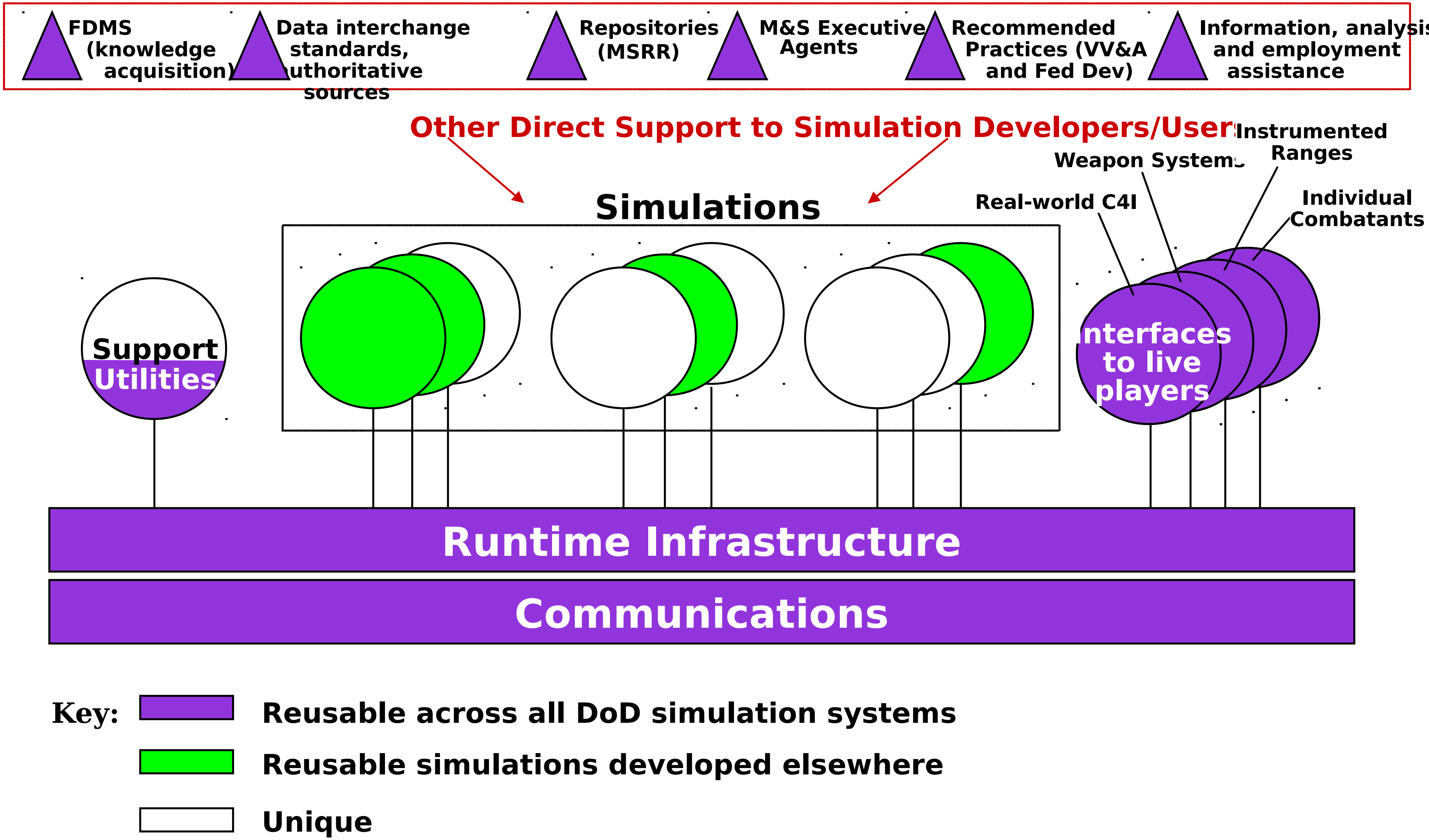
Technical Interoperability

the capability of federates (simulations) to physically connect and exchange data

Substantive Interoperability

the capability of federates when joined together to provide adequate, accurate, and consistent simulated representations which adhere to the principles of “fair fight”and address the mission objectives

Technical Interoperability



Technical Interoperability

- Characterized by the ability of federates to ***physically connect and exchange data*** in accordance with the FOM
- Involves the use of common standards, compatible interfaces and coordinated data structures
- Elements of technical interoperability
  - Hardware compatibility
  - Standards compatibility
  - Time management coordination
  - Coordinated use of RTI services
  - Security issues

supported by HLA infrastructure

Technical Interoperability (cont'd)

- **Standards compatibility**
  - HLA standards: Insure that federates have compliant interfaces to API associated with the same version of the HLA specification
  - Other standards: Comply with the standards imposed by operating systems, programming languages and network protocols used in the implementation
- **Hardware compatibility**
  - Establish physical connectivity between computing and data storage resources for the federation
  - Insure that heterogeneous computers interpret data exchanges correctly (e.g., data format & byte-alignment compatibility)
  - Balance CPU resources against federate needs to allow federates to process data as efficiently as needed
- **Time management**
  - Correctly use the Time Management Services provided by the RTI to facilitate interactions between dissimilar simulations

Technical Interoperability (cont'd)

- RTI Services
  - Correctly use of RTI Services by each federate and the federation as a whole, particularly
    - Synchronization point services
    - Save and restore services
    - Data distribution management services
- Security
  - Address the security issues needed to protect the federation's operation including
    - Data encryption
    - Enclave partitioning
    - Safe data exchanges between enclaves with different classifications

Resolving technical interoperability problems insures that the federation will run but does not guarantee that the federation can accomplish its mission.

High Level Architecture

- The High Level Architecture (HLA) provides
  - a runtime software architecture for distributed simulation
  - a framework and set of capabilities to support design and execution of simulation applications
- HLA developers are responsible for composing federations in meaningful ways to solve real world problems
- Validity problems of individual simulations are the responsibility of the federation development team

The federation manager and developer must insure that selected federates interoperate in a manner that technically and substantively support the federation requirements.

HLA and Interoperability

HLA alone cannot guarantee that federates will only interact in valid ways. If you can solve the hardware compatibility and security issues for your federation, then HLA can support its technical interoperability.

HLA supports the technical interoperability between distributed simulations. Substantive interoperability, on the other hand, remains a key challenge to achieving complete distributed simulation interoperability. [Dahmann et al.]

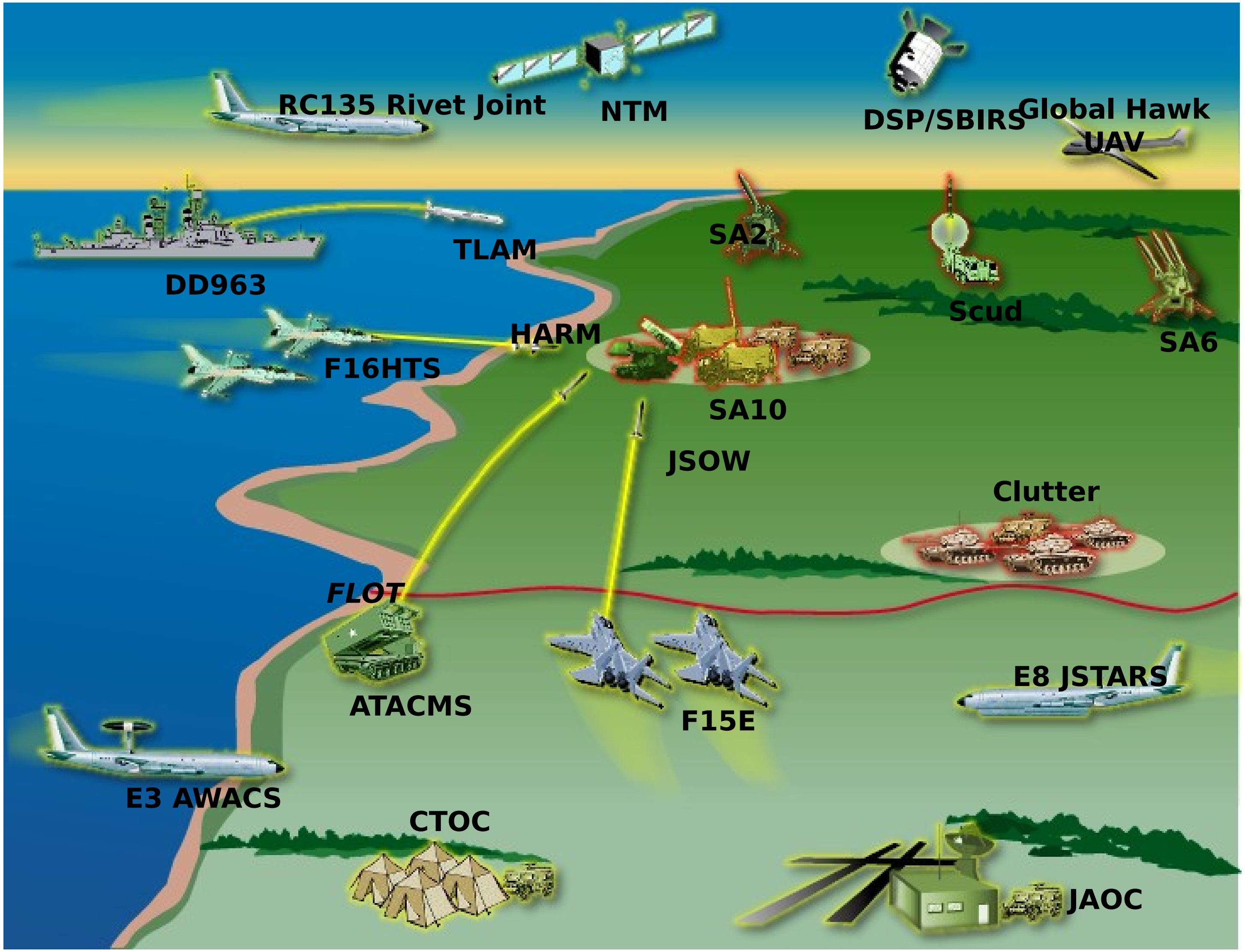
I think that I understand technical interoperability and HLA's role in it, but what is substantive interoperability and how do I get that?

Substantive Interoperability

Simulations abstract the actual world in their representations, sometimes in very different ways. These differences cause validity problems when the simulations share aspects of their representations to build an integrated simulated world.. Substantive interoperability addresses validity problems at the representational level. Thus, it depends directly upon the purpose your federation serves and encompasses two primary facets of the simulated world:

- Interoperability among entities
  - Logical interaction between entities modeled in different federates
  - Temporal resolution
  - Spatial resolution
- Contextual effects on interoperability
  - Coherent relationships between the components of the physical environment: ground, ocean, atmosphere, weather, infrared, and electromagnetic

Substantive Interoperability



Entities - Logical Interaction

- **Level of Representation**
  - Are the needed entities available in the federation at the level of detail necessary?
  - Do the entities generated by the various federates “fit” together?
- **Entity Attribution**
  - What are the critical characteristics of real-world entities required in the federation?
  - Do the entity models possess the key attributes salient to the federation purpose?
- **Entity Behaviors**
  - Can the entity models carry out the behaviors needed?
  - Do entity models in different federates work together logically?
  - Are the algorithms used by the federates to compute effects consistent across the federation?

Entities - Logical Interaction (cont'd)

- **Sample questions to ask…**
  - Do opposing force entities have a legitimate chance to detect and engage each other?
  - Do friendly force entities share battlefield situation data fairly or is the "blue picture" provided universally to all friendly entities? Does it matter?
  - Are some entities degraded by adverse environmental conditions while others are not?
  - Do any entities use ground truth data to compute firing solutions? Is that acceptable?
  - Do combat algorithms rely on unaccredited data values (or data values not derived empirically)?
  - Are combat algorithms applied consistently in all federates?

All entities need not be represented at the same resolution, but interactions between entities must meet the needs of the federation.

Temporal Resolution

- **Each simulation computes changes in the state of the entities at some resolution of simulation time.**
- **Are incremental state changes computed often enough to allow**
  - logical interaction between entities?
  - needed data to be collected?

All federates in the federation do not have to resolve time at the same level. The RTI time management services support synchronization of individual federate time and that helps to match differing temporal resolutions.

Spatial Resolution

- Each simulation computes the location of entities based on a specific geo-spatial reference system (standard or otherwise)
- Are entity locations computed and shared in a way that allows different federates to adequately 'fix' an entity consistently in property space (including geo-location but other properties as well)?

All federates in the federation do not need to compute and store entity spatial data in the same reference frame. But when sharing spatial data among federates, the solution must support the desired outcomes of the application.

Contextual Effects on Interoperability

- **Federates must have a sufficiently consistent, correlated view of the *environment* to support the needs of the application**
- **Includes *visual* and *non-visual* aspects of the environment**
  - Buildings, bridges, roads, power lines
  - Infrared radiation, radar reflectivity
- **Early solutions were achieved by developing a *mapping* between the different environmental representations of simulations that were required to interoperate or by *enforced homogeneity***

Contextual Effects on Interoperability (cont'd)

- **Current solutions look to establish access to *integrated data set(s)* with a standard syntax and semantics…using the SEDRIS data reference model (DRM), data dictionary, data coding standards (DCS), and a standard interface specification.**

- **Beyond the representation of the environment itself, there must be consistent portrayal of the**
  - Effects *of the environment* on systems and human behaviors (e.g. precipitation increases soil moisture content which in turn decreases trafficability
  - Impacts *of systems and humans* on the environment (e.g., weapons effects cause craters, combat engineers use heavy equipment to create berms or repair runways)

Example: C3 Interoperability

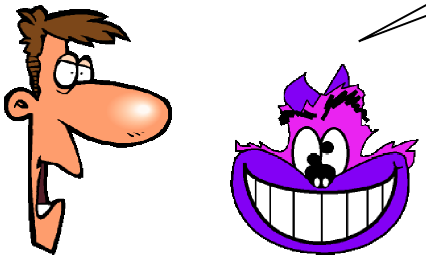
- **Representation of C3I in combat simulations poses particular challenges for simulation interoperability**
- **Potential incompatibilities or inconsistencies can occur in several areas**
  - Portrayal of command organizations and the C2 process
  - Exchange of C2 orders and reports
  - Impact of communication effects upon C2 information flows
- **Incompatibilities can lead to inappropriate results or catastrophic impacts on the simulation scenario (e.g., subordinate units that fail to receive or understand the incoming order may stop dead in their tracks)**

See - S.Y. Harmon & S.M. Youngblood, "Fidelity and Human Behavior Representations," Paper # 01S-SIW-113, Proc. Spring 2001 Simulation Interoperability Workshop, Orlando, FL, March 2001.

Representational Anomaly Types

OK, I know the general characteristics of substantive interoperability but how can I recognize substantive interoperability problems when they occur?

Any substantive interoperability problem will manifest itself as one of three types of representational anomalies.



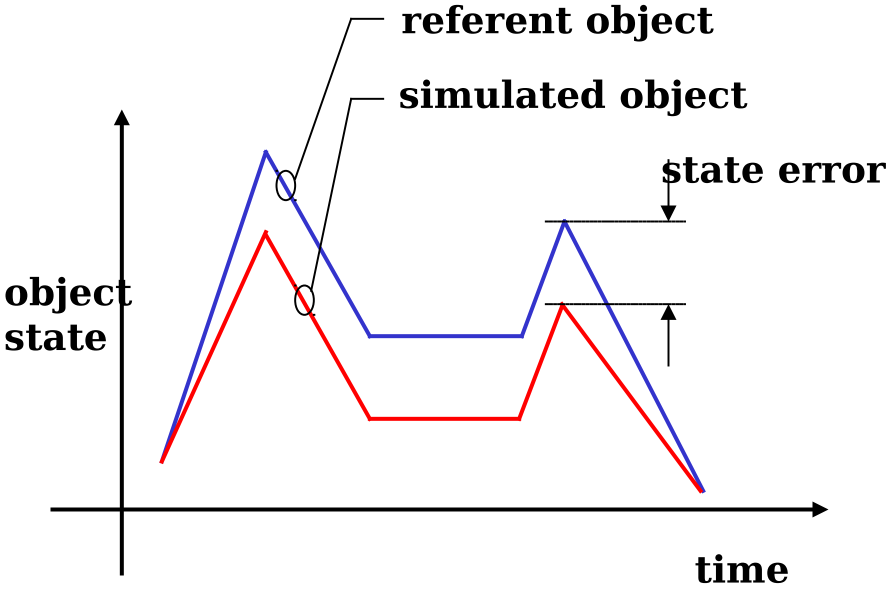
1. State Error Anomalies
2. Event Ordering Anomalies
3. Event Phase Anomalies

See - S.Y. Harmon & S.M. Youngblood, "Leveraging Fidelity to Achieve Substantive Interoperability," Proc. Spring 2001 Simulation Interoperability Workshop, Paper #01S-SIW-114, Orlando, FL, March 2001.

Representational Anomaly Types (cont'd)

State Error Anomaly

When a difference occurs between the state a simulated object assumes and the state that object's referent assumes under identical conditions and that difference is beyond levels tolerable by the application

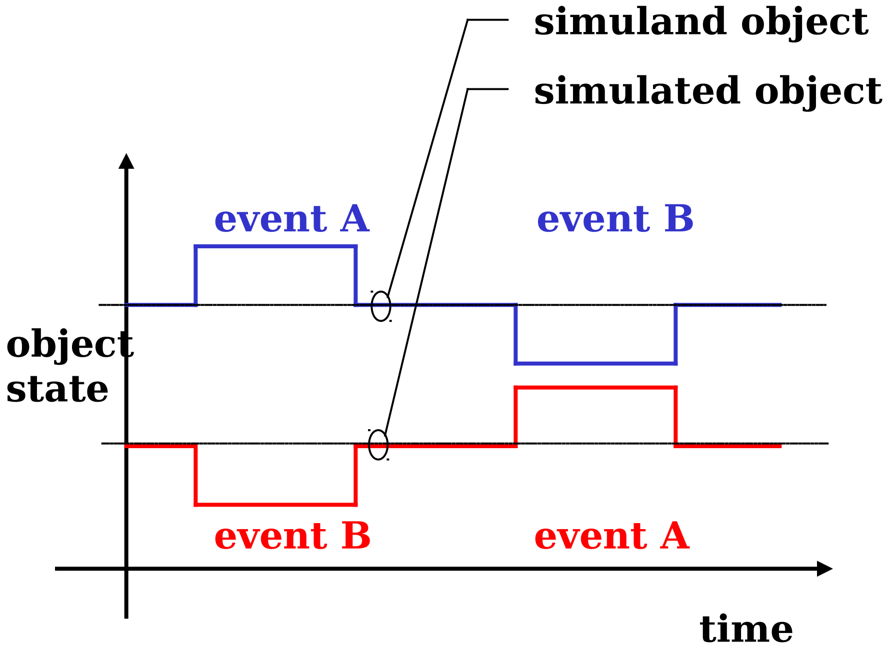


Example: positional inaccuracies in the trajectories of moving objects due to approximations of the gravitational constant or friction coefficients

Representational Anomaly Types (cont'd)

Event Ordering Anomaly

When a simulated object produces the same events that the simuland would under identical conditions but in a different order

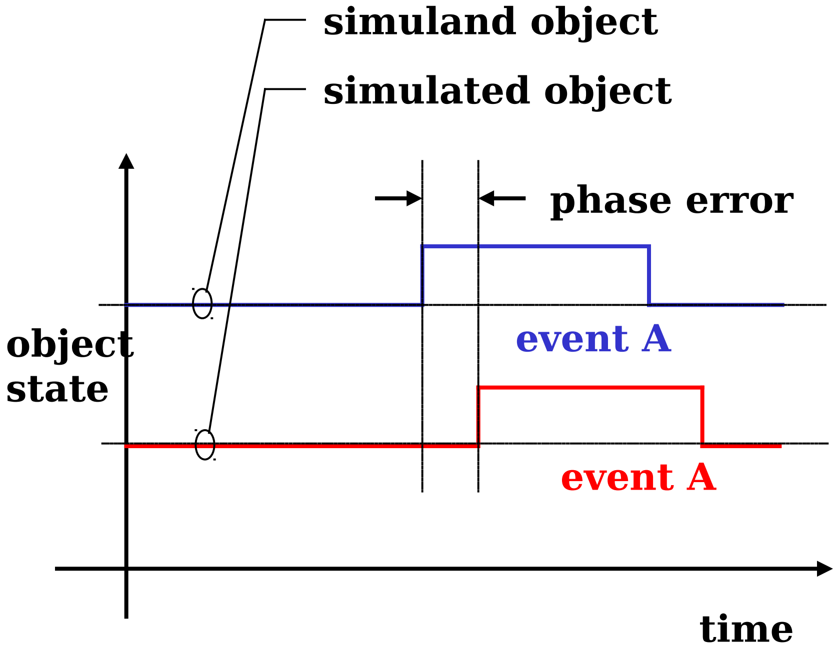


Example: a detection algorithm with a stochastic component acquiring a more distant target before acquiring a nearer target

Representational Anomaly Types (cont'd)

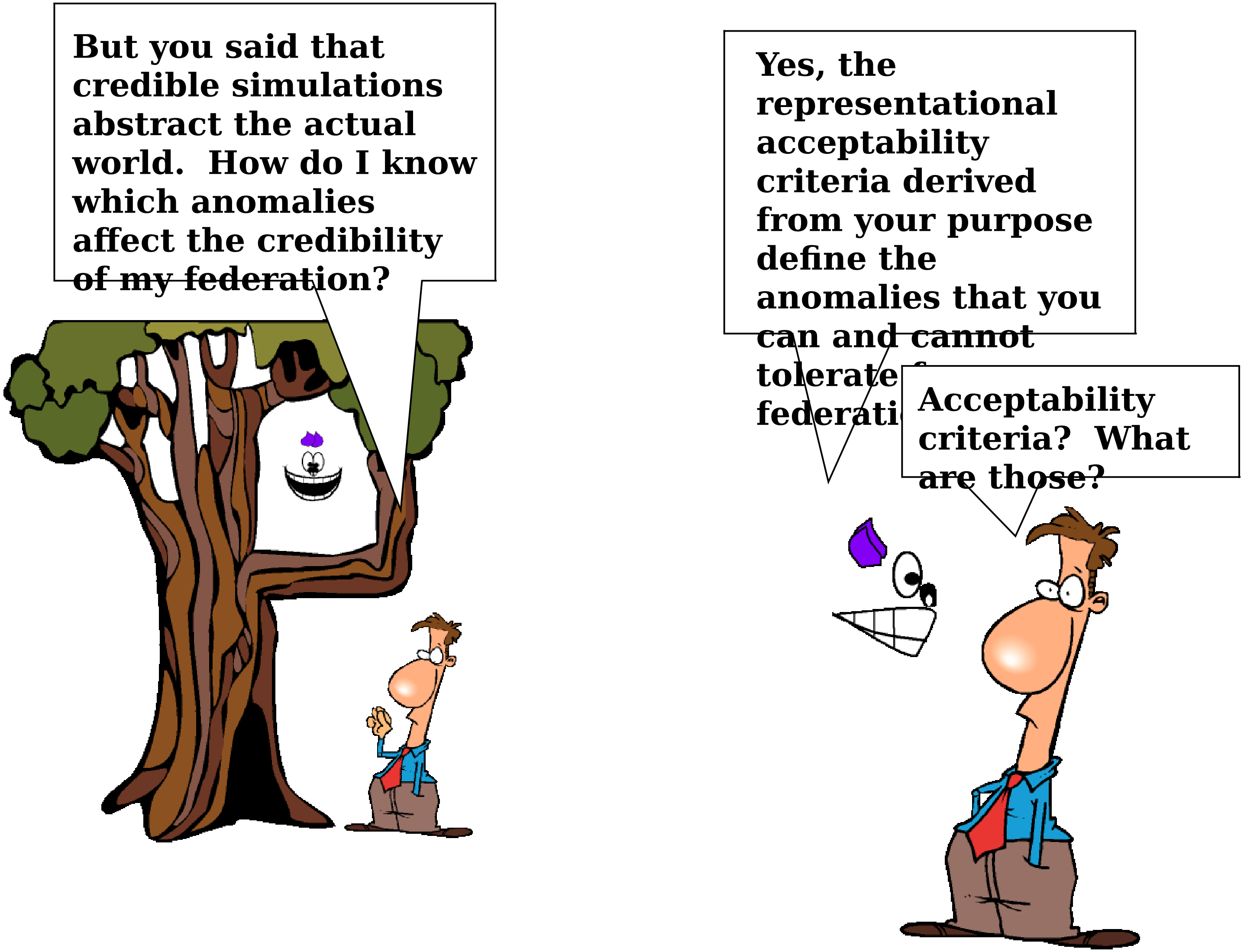
Event Phase Anomaly

When a simulated object produces the same events in the same order that the simuland would under identical conditions but with a timing or phase error



Example: inaccurate decision times due to approximations of decision latencies could lead to one example

Representational Acceptability Criteria



Representational Acceptability Criteria

- **Representational acceptability criteria define the gates through which the representational capabilities of a simulation must pass to suit a purpose**

- **Acceptability criteria link all of the roles involved in federation design and development:**
  - Users generate them, either directly or indirectly (derived by others from user-generated needs or requirements)
  - Developers design and implement to satisfy them
  - V&V agents evaluate federation capabilities against them
  - Accreditation agents make their accreditation recommendations based upon them

Representational Acceptability Criteria

- **The importance of acceptability criteria means that they should be**
  - Necessary to the purpose
  - Specific
  - Measurable
  - Complete

- **Acceptability criteria that do not meet these standards can lead to several problems:**
  - Communication difficulties between the various roles
  - Schedule and cost overruns
  - Unnecessary technical challenges
  - Federations unable to achieve the user's purpose

Substantive Interoperability Conditions

These criteria define what state and behavior you must represent in your federation's simulated world and how well. Intolerable representational anomalies can arise from invalid federates and from the interactions between valid federates. The latter create substantive interoperability problems. To locate the sources of interoperability-related anomalies you must test your federates under two conditions:

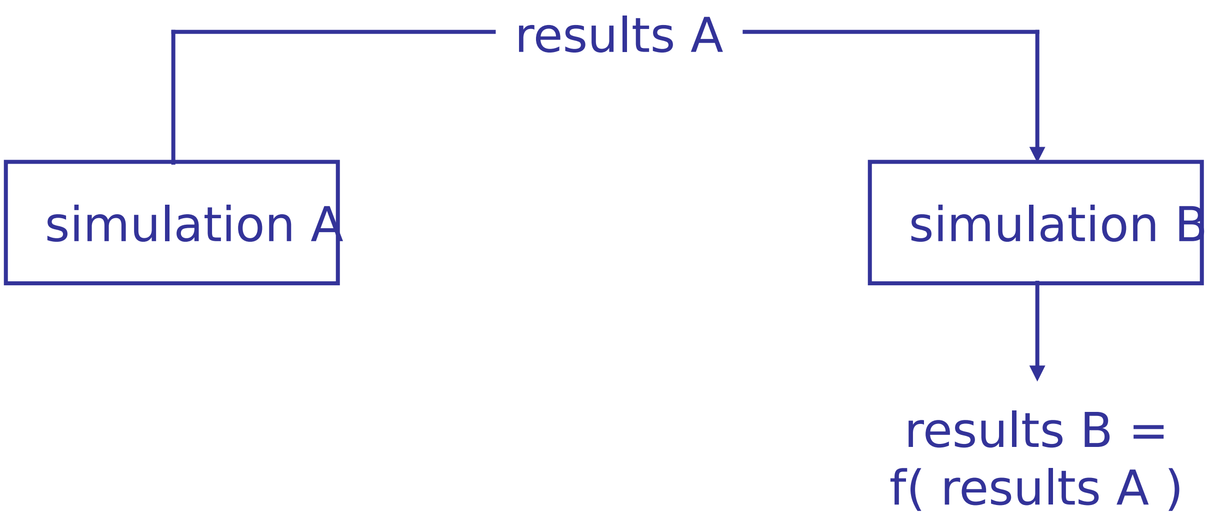
1. Functional Compositions

2. Manifold Representations

See - S.Y. Harmon & S.M. Youngblood, "Leveraging Fidelity to Achieve Substantive Interoperability," Proc. Spring 2001 Simulation Interoperability Workshop, Paper #01S-SIW-114, Orlando, FL, March 2001.

Functional Compositions

Functional compositions occur when the computation of one or more object states in one simulation depend upon the data provided by another simulation.

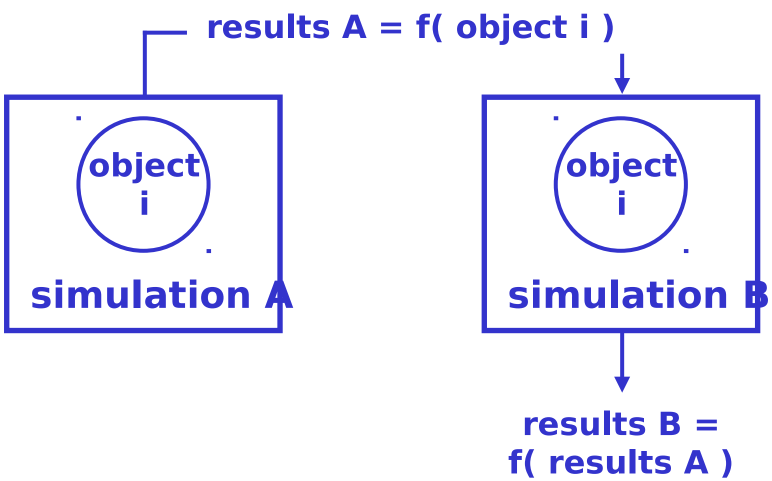


Functional Composition Interoperability Criteria

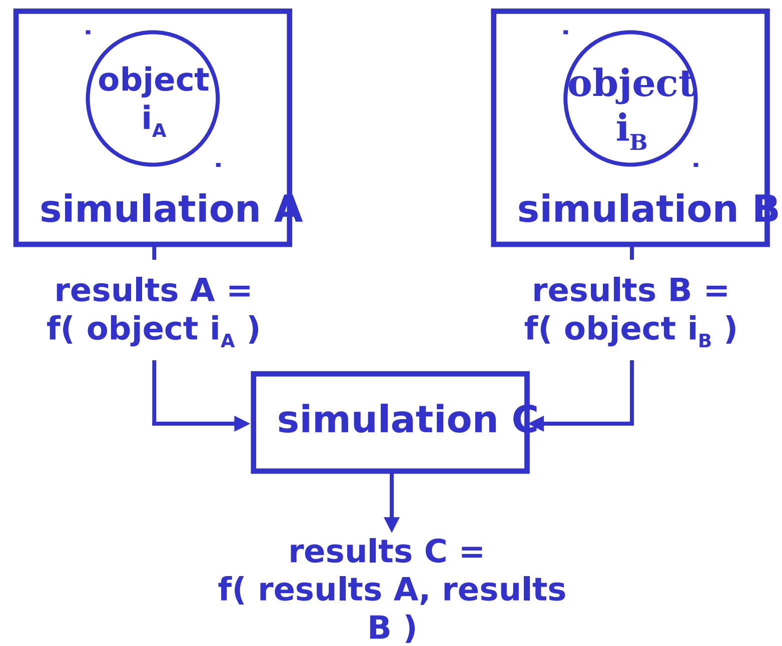
Criterion	Definition
dependency representation	a functional dependency relevant to the simulations' purpose is represented where one exists & that dependency represents the relevant independent & dependent variables
representational accuracy	a simulated dependency produces results that are within the desired accuracy for the application
range consistency	the range of results A maps completely into the domain of f(results A) = results B
sensitivity consistency	precision of results A ≥ sensitivity of results B to results A
temporal representation	the smallest time interval to which simulations A & B are sensitive ≤ the smallest time interval within which the physical processes they represent can change state significantly (where the purpose to defines significance).
interval sensitivity	smallest time interval to which f(results A) can respond ≤ smallest time interval that simulation A represents when producing results A
error consistency	if simulations A & B represent objects with properties measured in intersecting metric spaces then the errors of those properties must be equal where those properties provide values for dependent functions.

Manifold Representations

Manifold representations occur when two or more simulations represent the same state or behavior of the same object & interact either directly or indirectly.



Directly Interacting Simulations

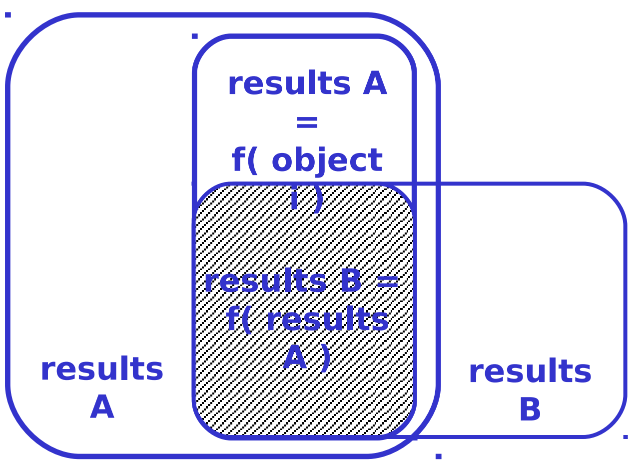


Indirectly Interacting Simulations

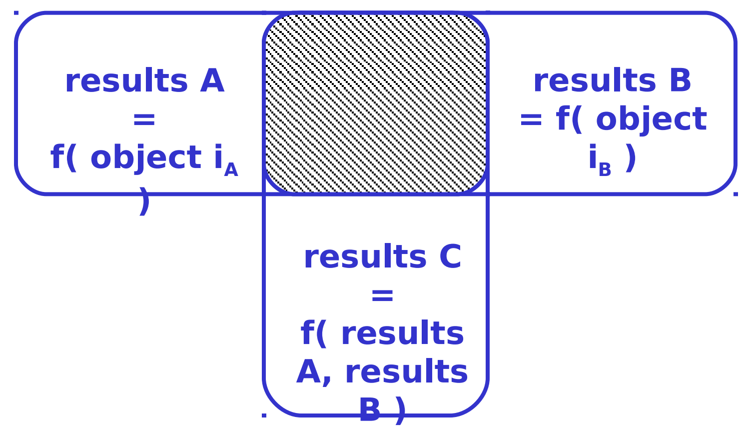
Manifold representations most often serve as computational conveniences to reduce communications burdens.

Manifold Representations & Time

Manifold representations only pose problems only under very specific conditions.



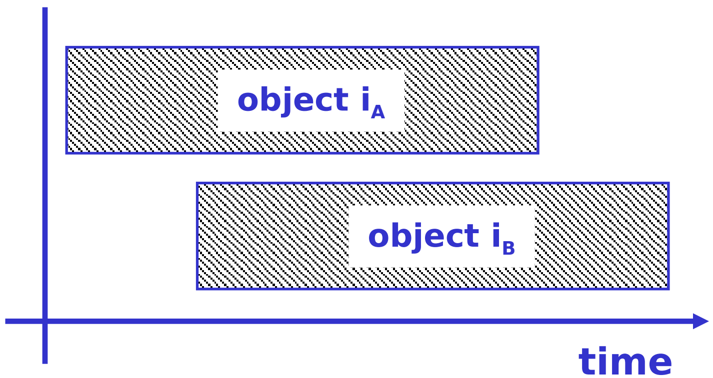
Conditions for Directly Interacting Simulations



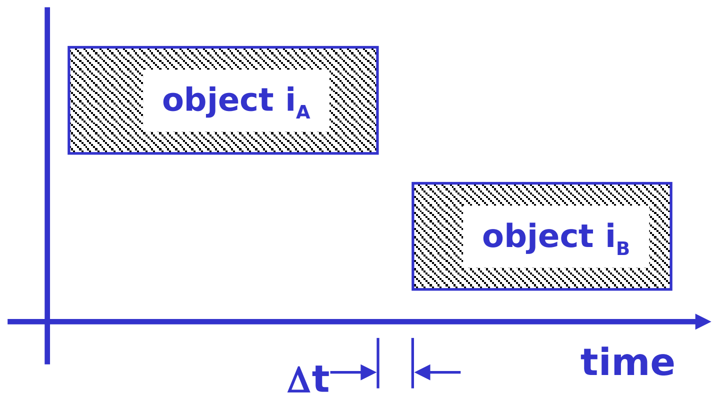
Conditions for Indirectly Interacting Simulations

Manifold Representation Interoperability Criteria

Both parallel & sequential manifold representations can lead to substantive interoperability problems.



Parallel Representations in Time (e.g., dead reckoning)



Sequential Representations in Time (e.g., aggregation/disaggregation)

Manifold Representation Interoperability Criteria

Criterion	Definition
state correspondence	the difference between manifold object state representations ≤ a tolerable threshold over the entire range of valid interactions & the phases of state changes of simultaneously existing manifold representations must correspond within the acceptable tolerances
abstraction transform	an abstraction transform function must exist for manifold representations at different levels of abstraction; this transform may also need to (1) exist within the functions dependent upon information from multiple manifold representations (2) remain continuous over the union of the domains of all of the functions that depend upon those representations, & (3) be invertible.
state continuity	the meaningful hand-off from one manifold representation to another must exist if a time interval gap exists between the execution of those representations

The continuity criterion preserves the causal relationships between the manifold representations & the other models in a distributed simulation.

Conceptual Model Definition

Wow! These tests will require a lot of information about my federates. Does the federation object model contain all of it?

No. You should assemble a conceptual model for your federation that contains the necessary information.

Simulation conceptual model

developer's translation of modeling requirements into a detailed design framework, from which the software, hardware, networks, and systems/equipment that will make up the simulation can be built

See - Dale K. Pace, "Simulation Conceptual Model Role in Determining Compatibility of Candidate Simulations for a HLA Federation," Proc. 2001 Spring SISO Simulation Interoperability Workshop, Orlando, FL, March 2001.

Conceptual Model Standards

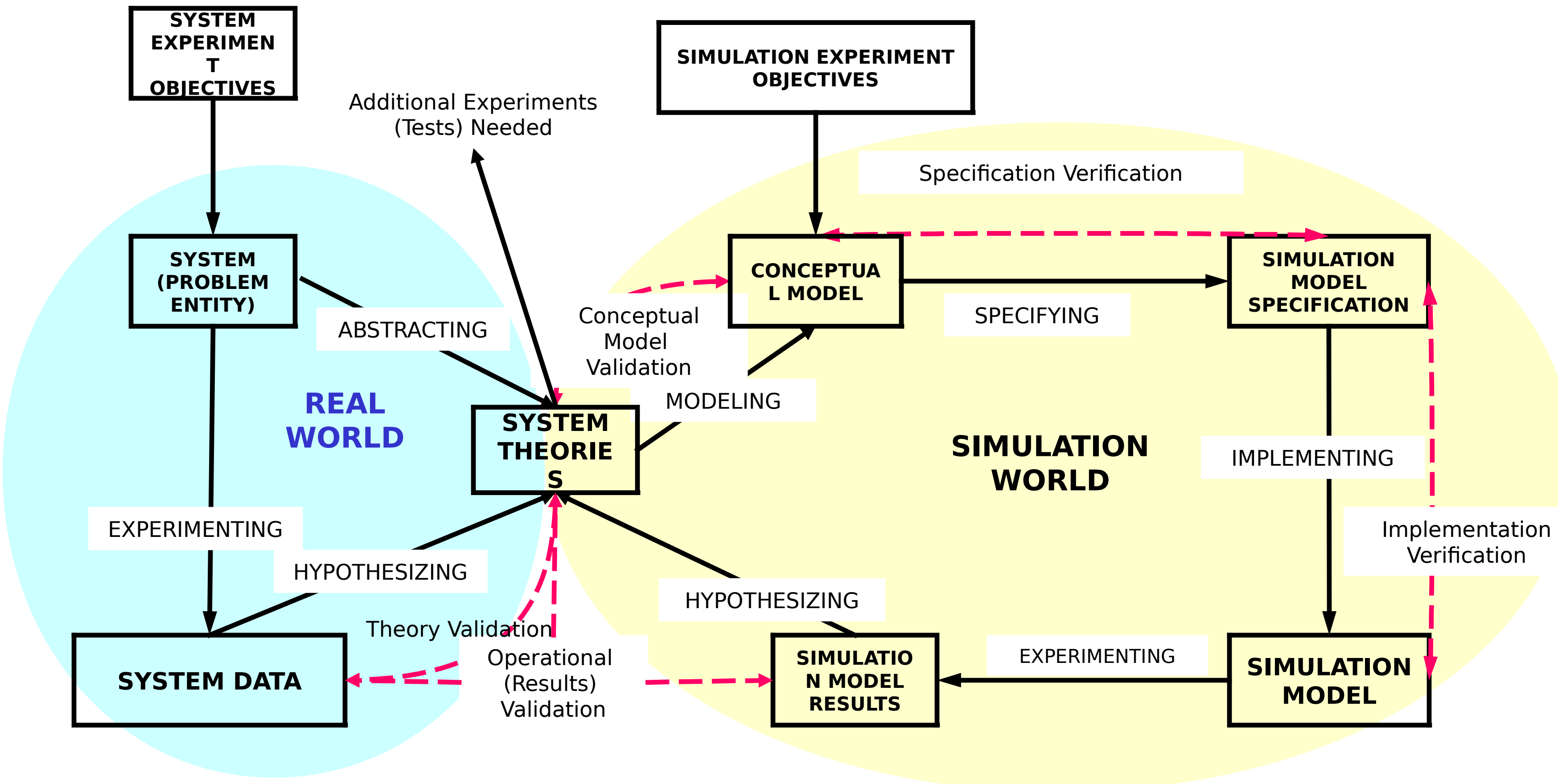
Currently

- **Standards exist for**
  - describing systems that exchange information (JTA)
  - interoperability among simulations (HLA)

- **No standards exist for**
  - simulation decomposition into entities and processes
  - representation abstraction of the subject simulated
  - how to document the simulation conceptual model

Sargent Diagram

Real World & Simulation World Relationships in Developing System Theories and Simulation Models with Verification and Validation (V&V) -- additional explanation in annotation



Notes:

Experiment objectives should derive from validated requirements

Dotted red implies comparison, assessment, or evaluation

Validation is always relative to objectives/requirements/intended use

Conceptual Model & Simulation Management

- **A good conceptual model can improve requirements**

- **Good requirements are important because**
  - *Faulty requirements cause half of software errors*
  - *Late error detection/correction is much more expensive than early error detection/correction*

- **A good conceptual model allows early**
  - *Estimation of simulation fidelity*
  - *Assessment of simulation validity for the purpose*

See - Dale K. Pace, "Simulation Conceptual Model Issues : Development Methods (Part 1), Interaction With Simulation Requirements (Part 2), and Impact on Simulation Development Costs and V&V Costs (Part 3)," Proc. 2000 SCS Summer Computer Simulation Conference, W.F. Waite, ed., July 20000, Vancouver, British Columbia, Canada, pp. 488-499.

Three Primary Conceptual Model Components

Requirements

Specifications

(1) Simulation Context

Authoritative Information re: relevant entities/processes, data, algorithms, assumptions, behaviors, etc.

Sets constraints/bounds on the Simulation Concept

Constraints

Conceptual Model

Simulation Concept

(2) Mission Space -- Representation Aspect

Simulation Elements

Entities/processes represented (tasks, actions, behaviors, etc.) by assumptions, algorithms, data, and relationships (architecture)

(3) Simulatio

Steps in Conceptual Model Development

Iterate

Step 4: address relationships among simulation elements

Step 3: develop simulation elements (i.e., Representational Abstraction)

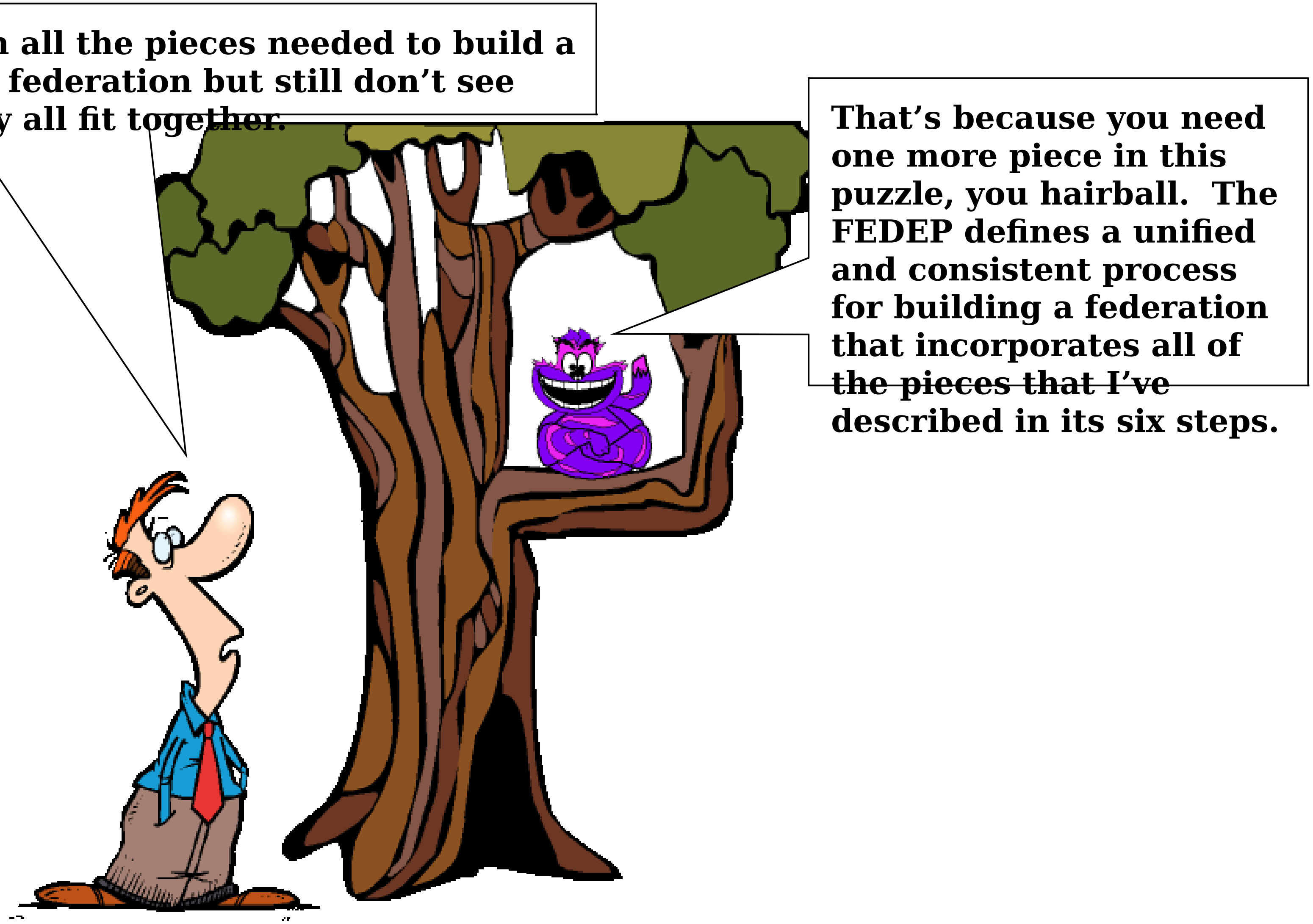
Step 2: identify entities and processes for representation (i.e., Conceptual Model Decomposition)

Step 1: collect authoritative simulation context info

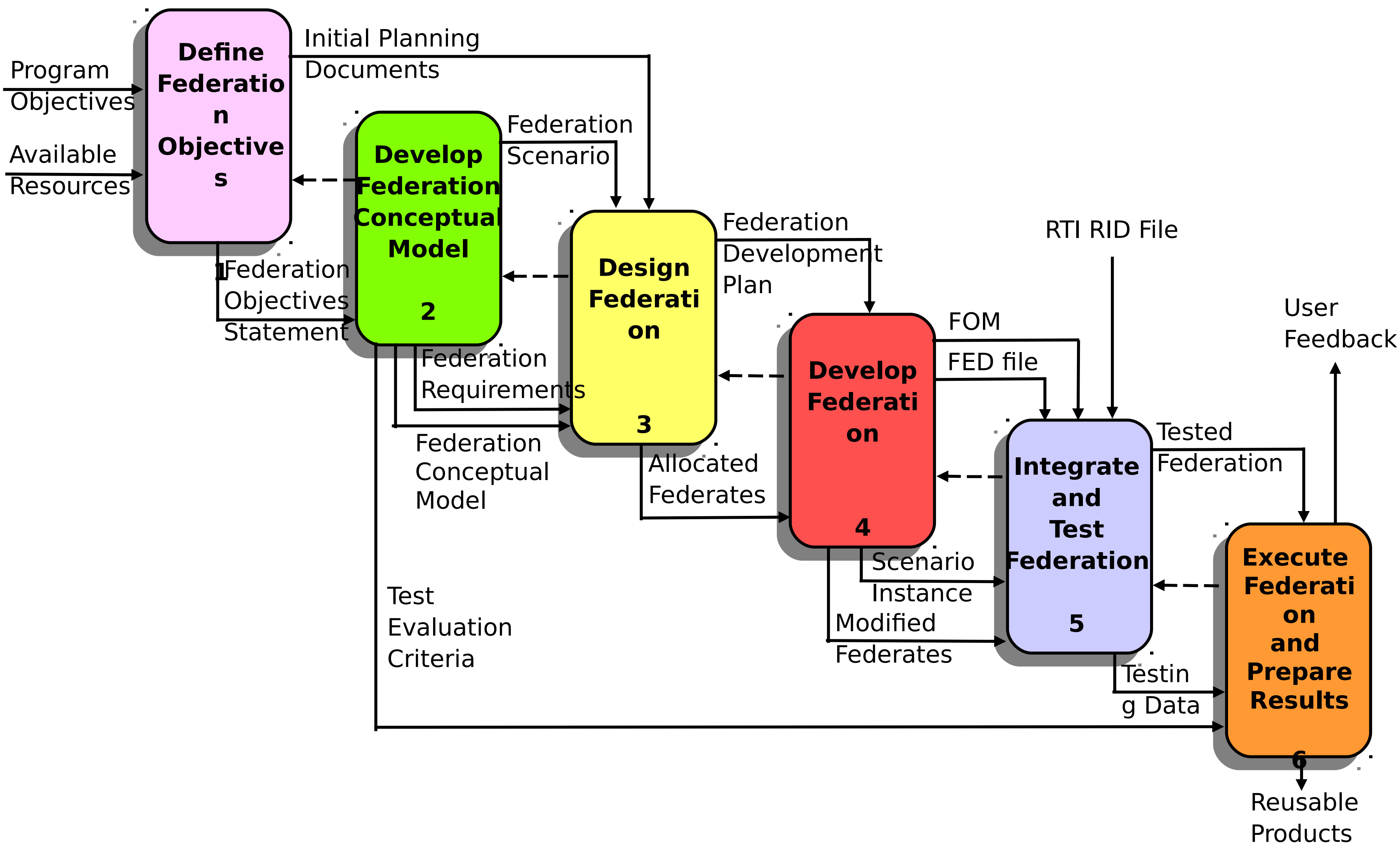
Conceptual Model Documentation

1. Conceptual Model Portion Identification
2. Principal Simulation Developer POCs
3. Requirements and Purpose
4. Overview
5. General Assumptions
6. Identification of Possible States, Tasks, Actions, and Behaviors, Relationships and Interactions, Events, and Parameters and Factors for Entities and Processes being described
7. Identification of Algorithms
8. Simulation Development Plans
9. Summary and Synopsis

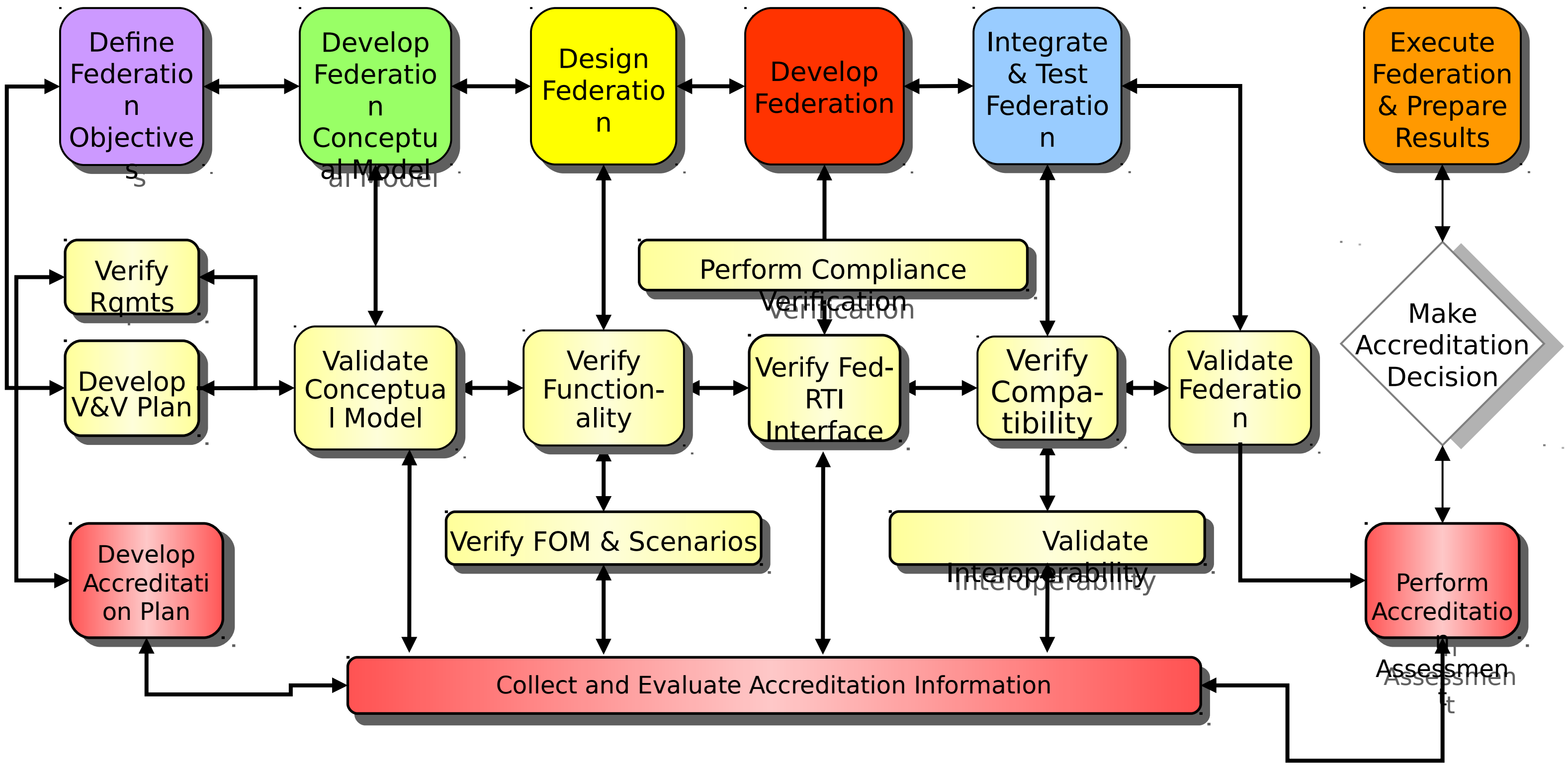
FEDEP & Interoperability



FEDEP Six Step Process



FEDEP and VV&A



Summary

1. Start with federates valid for your purpose
2. Use HLA to support technical interoperability
3. Define the representational acceptability criteria for your purpose
4. Build a conceptual model for your federation from the characteristics of your federates
5. Test the functional compositions and manifold representations for substantive interoperability
6. Follow the FEDEP and its